

# Physical Morphology of Galaxies using Asymmetry

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**Abstract.** We demonstrate in this paper the use of asymmetry in conjunction with the integrated (B-V) color of galaxies for physical morphological purposes. We show how color-asymmetry diagrams can be used to distinguish between various types of galaxies, including ellipticals, late and early type disks, irregulars and interacting/merging galaxies. We also show how asymmetry can be used to help decipher the morphology of nearby starbursts, and galaxies in the Hubble Deep Field.

**Keywords:** galaxies: morphology, color, asymmetry, structure

## 1. Introduction

Observable properties of astrophysical objects increases our knowledge of them; the more properties, the better we are able to make characteristics. In astronomical imaging, or spectroscopy, the extended structure of galaxies offers many advantages, most of which have not been thoroughly explored. Extragalactic studies have an advantage over stars in this regard, since a stellar image contains only magnitude and color information. For this reason, classification of stars has been based on their spectrum. However, an image of a galaxy is full of morphological detail that can be effectively exploited.

A host of these photo-morphologic properties can be determined, that include, but are not limited to: magnitudes, colors, color gradients, morphology, light concentrations, surface brightness, and asymmetry. The last of these, asymmetry is one of the hardest of these parameters to measure, but is a powerful tool that can be used to determine both morphological and physical parameters of galaxies.

Asymmetry can be measured in a several different ways. These include: Fourier component analysis (e.g. Rix & Zaritsky 1995), searches for azimuthal deviations (e.g. Kornreich et al. 1998), or by the use of radial 180° rotations (Conselice 1997; Conselice, Bershadsky, & Jangren 2000). The asymmetry algorithm used in this paper is described in detail in Conselice et al. (2000). Improvements of this method over previous asymmetry computations (e.g. Abraham et al. 1996; Conselice 1997) include a robust method of finding the center of rotation which effectively iterates to find the minimum asymmetry, as well as using a standard non-isophotal radius.



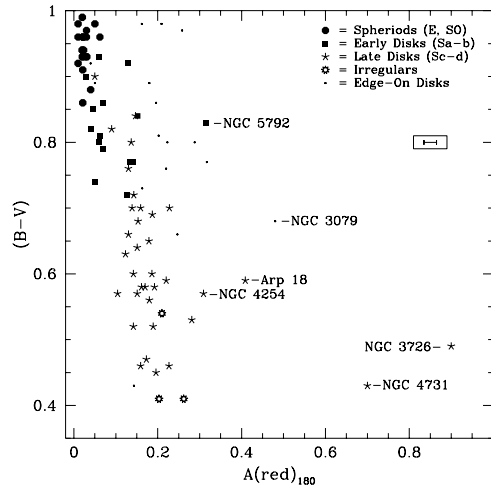


Figure 1. Color-Asymmetry Diagram for Nearby Galaxies. Labeled galaxies are interactions/mergers.

How asymmetry is useful as a morphological diagnostic is the focus of this paper; we will show how this parameter can be used in several extragalactic environments.

## 2. Nearby Galaxy Color-Asymmetry Diagram

Comparing asymmetry with the color of a galaxy can reveal important physical and morphological information. Shown in Figure 1 is the color-asymmetry diagram from a sample of 113 galaxies taken from the Frei et al. (1996) catalog. These 113 galaxies sample all Hubble types, including inclined and peculiar galaxies.

There are several features in Figure 1 worth noting. Most of the galaxies fall along a fiducial sequence that expresses the correlation between color and asymmetry. Most galaxies get bluer that as they get more asymmetric. This is true for all Hubble-Types from ellipticals, through spirals to irregular galaxies.

An equally important property of this diagram are the galaxies that do not fall on or near the fiducial sequence. Some of these are galaxies that are inclined, and therefore have a morphology driven by projection effects. The galaxies in Figure 1 that are inclined are noted as tiny dots.

The galaxies in Figure 1 that are too asymmetric for their color, but are not inclined show evidence for recent interactions and mergers. Galaxies considered from other considerations as an interaction/merger are label with their names. Most of these are significantly displaced

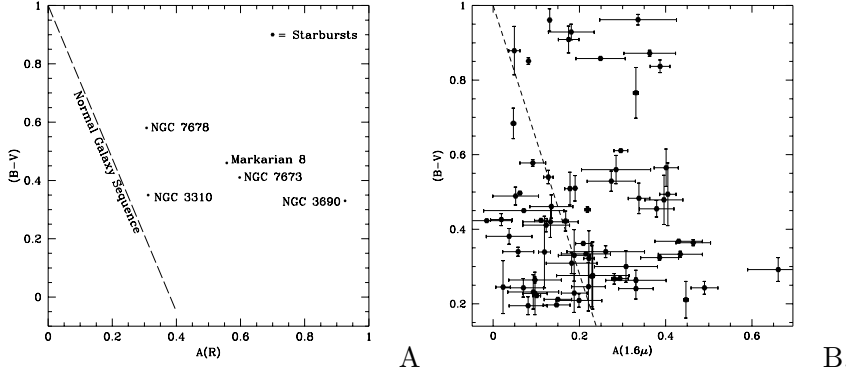


Figure 2. A) Color-Asymmetry Diagram for Starbursts B) Color-Asymmetry Diagram for galaxies in the HDF

from the fiducial color-asymmetry sequence. The power of the color-asymmetry diagram is this ability to automatically sort out in a sample of galaxies, which ones are likely the result of an interaction/merger.

### 3. Physical Morphology at High Redshift

The power of asymmetry also lies in its ability to determine the history of a galaxy, and whether or not it has undergone a recent interaction. This is important for understanding galaxies in a host of environments, but can also be useful for determining possible trigger mechanisms for starbursts and other morphologically peculiar galaxies.

In Conselice et al. (2000; in prep) we show that by using the color and asymmetry of starburst galaxies, it is possible to determine if the triggering mechanism for starburst involved a galaxy interaction/merger, or if the likely triggering mechanism is a bar-instability or another internal event. Figure 2a shows the color-asymmetry diagram for a sample of nearby starbursts, most are consistent with a merger/interaction, except for NGC 3310 which was probably triggered by a bar-instability. We can quantitatively compare nearby starbursts with high redshift galaxies to determine if these two populations are similar, as has been suggested.

To compare nearby and distant galaxies, we compute the asymmetries of galaxies in the NICMOS images of the Hubble Deep Field in the H band ( $1.6\mu$ ). We also use k-corrected (B-V) colors of these galaxies, based on 6 color photometry based on the technique of Bershadsky (1995).

Previous observations of galaxies at high redshift indicate that a large fraction are undergoing star formation (Steidel et al. 1996). These

galaxies are similar in structure to nearby starburst galaxies (e.g. Hibbard & Vacca 1997; Giavalisco et al. 1996) as well as more detailed morphological properties (Conselice et al. 2000; AJ in press). However, are both populations undergoing mergers/interactions, and what has triggered the star formation?

Star formation can occur by various methods, including interactions with other galaxies, as well as internal processes such as bar instabilities. The likely mechanism behind the triggering of a starburst event can be determined by finding its position on a color-asymmetry diagram. We must be cautious however, when attributing asymmetries in high redshift galaxies for an interaction, or merger. The peculiar forms seen in these galaxies could in some cases result from the initial creation of these galaxies. However, Figure 2b does show that the majority of galaxies at high redshift have colors and asymmetries that are not consistent with normal nearby galaxies, even irregulars. The galaxies seen at high redshift are therefore either going through an interaction/merger or are in the process of stabilizing from their initial creation.

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